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COMPUTERIZED MACHINABILITY DATA BASE SYSTEMS AS APPLIED TO ECM AND EDM PROCESSES

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ABSTRACT

Computerized machinability data base systems are now becoming essential for automating process planning and programming in computer integrated manufacturing sytems. Non-conventional machining plays a significant role in modern high technology engineering processing and contributes to accuracy and component quality. Such processes are extensively used in the jet engine manufacturing and in machining turbine blades and dies. The obective of this work is to present a scientific approach for the application of integrated machining data selection systems to non-conventional machining processes namely, electrochemical (ECM) and electric discharge machining (EDM). The paper presents the choice and use of integrated machining data selection modelling systems with the ultimate goal to help manufacturers, workshop engineers and researchers to achieve optimum cutting conditions. The beneficial advantages of such work include efficient process planning under increased productivity conditions.

INTRODUCTION

Machinability data is used to aid in the selection of metal cutting parameters based on the machining process and on one or more production criteria. Some of these criteria may be accuracy, surface finish, power consumption or economy. Although machinability data selection plays an important role in influencing the machining operation still it depends to a large extent on personal experience.

Despite the fact that machining data Handbooks (1) satisfy most of the machinability data requirements, however, they cannot cope with every situation. In process optimization, Handbooks are not the most efficient machinability data banks, as

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the parameter required to be optimized may differ from one situation to the other.

By the time numerical control shared in the workshop, the programmer became more responsible than the operator in selecting the necessary machining data. Thus, machining technology decision became dependent on machinability data rather than being dependent on the experience of the machinist. The difficulty that faces NC programmers is that they are not well acquainted with metal cutting technology and that their experience is not sufficient to decide upon the correct working parameters. The case becomes more complicated when machining constraints such as sparking in ECM (2) and swarf coagulation in EDM (3) have to be considered. Such constraints limit feed rates in ECM and penetration rates in EDM. Thus, it becomes essential to supply NC programmers with appropriate machinability data systems.

With the ever-increasing developments in NC non-conventional machines, reliable machinability data becomes the required goal. Hence, it is necessaty to have a flexible system which has the ability to select and control the required machinability data. Such methods are known as Computerized Machinability Data Base Systems (CMDBS). The necessary step for accelerating CMDBS is the key to transfer machining data selection from an experienced-based discipline to a computerized information-based system. Zdeblick (4) outlined the philosophy of a machining data selection system which analyses and generates the required machining parameters for conventional workshop operations only.

Although computers are used in the selection of machinability data, however, it seems necessary to study and analyze the suitability of CMDBS as applied to non-conventional machining processes. With such processes the working parameters are more interacting than with conventional processes. With the rapid technological advancements in non-conventional processes it is essential to establish an integrated system which can help in achieving optimum working conditions.Besides,the paper presents the effect of the various working parameters on the resulting component accuracy. Moreover, possible machining constraints are discussed.

CLASSIFICATION OF CMDBS

The well known two categories of the CMDBS are the Stand-alone and the Integrated systems. The stand-alone category is a simple and direct Input/Output system, where the output is the recommended machining conditions for a given situation. Whereas, in integrated systems, the machinability information is automatically passed on to the next processing stage without any human intervention as in the stand-alone systems. Balakrishnan and Devries (5) grouped in tables the developers and the features of the existing CMDBS.

Computerized machinability systems rely on two important technics namely, mathematical modelling and data storage systems.

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1. MATHEMATICAL MODELLING SYSTEMS

By their nature such systems depend on analytical or empirical equations. The analytical equations are usually distinctive and closely related to the available experimental data, whereas the empirical equations are more generalised. A mathematical modelling program represents machinability variables in terms of the process working parameters. Generally, a machinability variable M, which represents surface finish, accuracy, tool life, ...etc, can be expressed by

$$M = f(a_1 , a_2 , a_3 , \ldots a_n)$$

where, a_1, a_2, ... a_n are process parameters related to the machining operation.

As a typical example, the mathematical equation defining tool life, L in an electrochemical drilling operation (6) is given by

$$L = N/(F.(b_1 + b_2.p + b_3.F/u))$$

where,
- N : total number of sparks which a tool can receive,
- F : tool feed rate, mm/min
- p : concentration of hydroxide suspension in the electrolyte, g/l
- u : potential difference, v
- b_1, b_2 & b_3 : constants depending on electrolyte.

Thus, the tool life, L as an output parameter can be determined given all the other factors for various experimental data. The coefficients of the mathematical model are obtained using regression analysis. With ECM operations tool life is considered to be one of the main parameters that control process economy.

The block diagram of Fig.1 shows a simple representation for the above mathematical model to achieve optimum working conditions.

2. DATA BASE STORAGE SYSTEMS

In this system the recommended working parameters are stored in files for various interacting combinations of the machining process. The recommended working parameters are taken either from workshop experience or Handbooks. Fig.2 shows a schematic layout for a data base storage system as applied to an EDM fine hole drilling operation.

By introducing the required inputs of the EDM process, the computer searches in the data base files for the most similar stored conditions and hence gives the output recommended conditions. The information files shown in Fig.2 perform the following :

i. Tool/Workpiece/Dielectric File: This file contains information concerning machinability characteristics of various tool/workpiece/dielectric combinations. As for example, graphite or

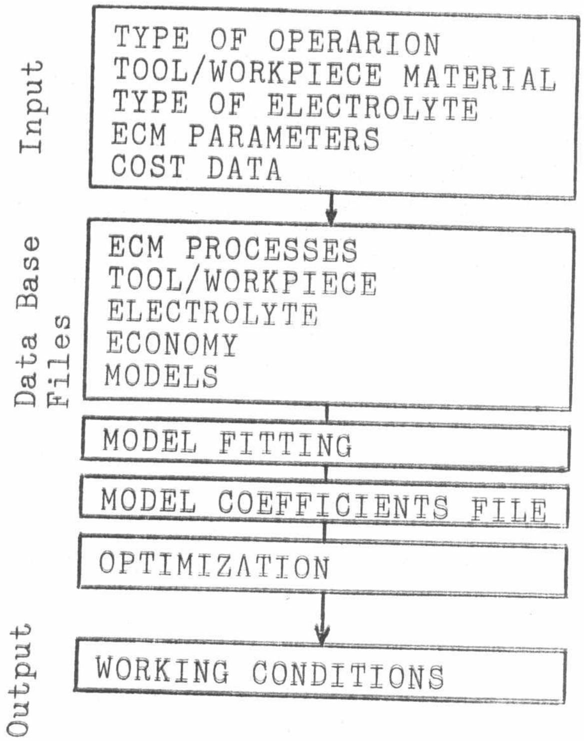

Fig.1 Schematic representation for a mathematical model.

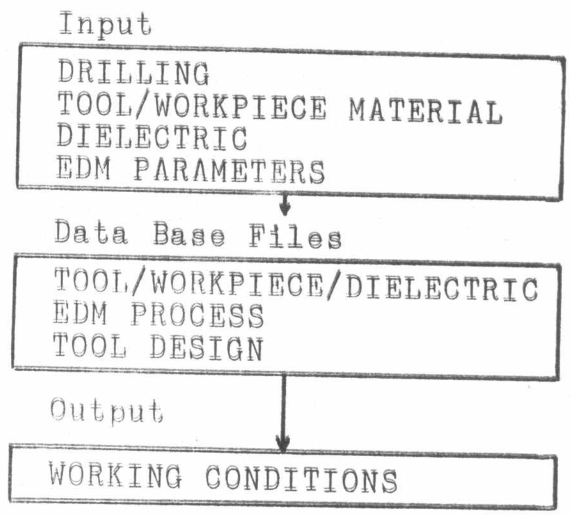

Fig.2 Layout of a data base storage system.

electrolytic copper tools when cutting in cast iron or hardened alloys using paraffin or kerosene dielectrics.
ii. EDM Process File: This file contains data defining the operating limitations for various EDM processes and ED machine types.
iii. Tool Design File: This file describes cutting tools in terms of geometry (shape, size and tolerance), surface finish and wear characteristics.

CRITERION DEVELOPMENT

In order to integrate machining data selection, it is essential to develop a criterion to define the specific machining problem. Also it is necessary to determine the priority by which the different criteria have to be ordered. Fig.3 shows an example of a criteria development system for non-conventional machining processes.

The INPUT block shown in Fig.3 contains data relating to the component required to be machined. Such data include geometry, material and pre-description of surface integrity of the component. By knowing such inputs the machining problem can be well defined. Thus, the criteria selection stage can be ready for functioning. The PROCESS AND OPERATION block (Fig.3), for example, groups

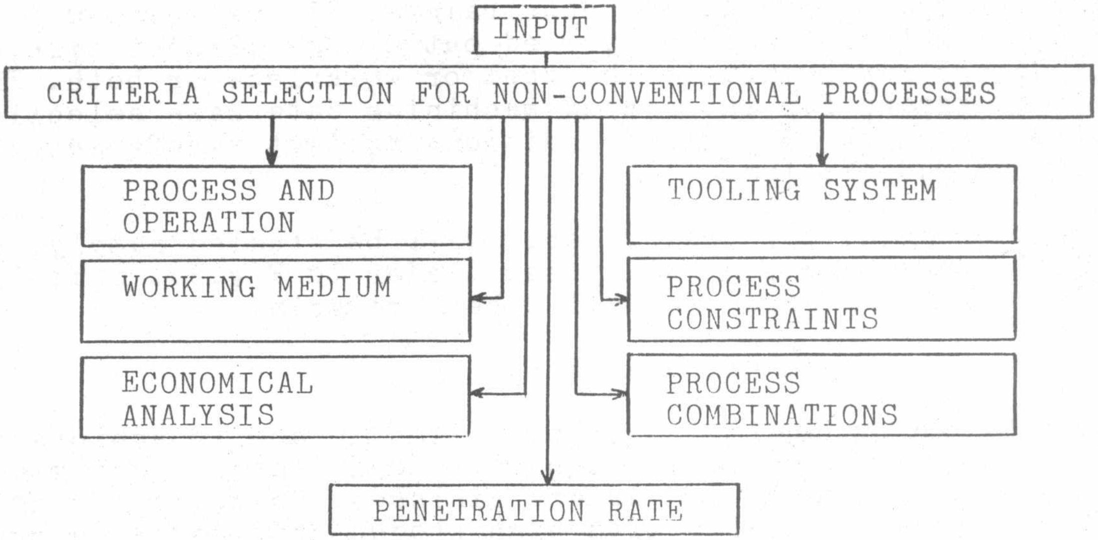

Fig.3 Criteria development system

all non-conventional machines regarding types, capacities and all possible operations each machine can perform as cavity sinking, broaching, wire cutting.... etc.

The final output from the criteria selection system should be able to define the following:-

1. Type of non-conventional process (ECM, EDM, ...).
2. Type of operation (drilling, broaching, ...).
3. Penetration rate (variable as with EDM or constant as with ECM).
4. Type of tool (material, shape, size, flushing holes, ...).
5. Tool wear (erosion rate as with EDM or sparking rate as with ECM).
6. Type of working medium (electrolyte for ECM processes or dielectric for EDM processes).
7. Necessary checks on process constraints.
8. Economical study (minimum cost, maximum production rate and maximum profit rate).
9. The necessity for more than one process (ECM only, EDM only, combined ECM and EDM).

The above defined nine criteria are independent and this advantage enables the system to be flexible and integrated. With the continuous developments in non-conventional processes new selection criteria can be directly added to the existing system.

CRITERION ANALYSIS

Each criterion for every specific machining problem has to be carefully studied. Also it should be remembered that every machining operation has its constraints. If the respond to a certain constraint is not carried out at the correct time, severe damage may result to the tool or workpiece or both. Thus, it is necessary for integrated machining data base selection systems to check machining conditions against a reference set of stored information.

As typical examples, two criteria will be studied namely, penetration rate and tooling system (refer to Fig.3). Similar studies could be given for all other criteria.

1. PENETRATION RATE

With EDM, the productivity problem lies in how to achieve optimum output conditions i.e. highest removal rates under minimum tool wear and acceptable surface finishes. To achieve consistent metal removal rates with high productivities it is necessary to optimize the EDM process as follows:

.. To perform a series of experiments to know how the rate of metal removal is affected by the different variables of the process.

.. To record the highest metal removal rates for the different combinations of the various parameters.

.. The above model can be repeated for various material/tool electrode/dielectric combinations, so as to obtain a complete data bank set which can be able to handle various working conditions.

The adaptive control system designed by Lascoe (7) was capable to utilize the available data for optimizing both roughing and finishing operations. The experiments were performed under manual and computer controlled operations. The results showed that under computer control, machining time dropped by about 26% than that of the manual operation. Christov (8) developed a model for the EDM process on the basis of primary data derived by statistical analysis of the main variables controlling a manufacturing plant. Also, Cornelissen et al (9) defined the performance of an EDM system in a three dimensional diagram representing removal rate, surface finish and relative electrode wear. This model is advantageous in comparing various EDM operation systems. All the above models can serve as possible guidelines for EDM data base systems.

By correct control of the ECM process we can attain maximum metal removal rates with high dimensional and shape accuracies under acceptable surface finishes. An adaptive on/off controller was designed by Larsson (10) to avoid tool damage through controlling the inter-electrode distance between the tool and workpiece. The on/off controller was developed to sense flow rates such that below a pre-set stored value, it stops the tool feed. The machining current was left on and when the flow increased as the gap widened, the tool feed was restarted. Such a data base system is beneficial in avoiding tool damage.

With ECM processes it is very essential to have in the data files a storage for the most possible constraints limiting the penetration rate. Such constraints can be summarized in the following:

i. Choking and Boiling Constraint.

The maximum penetration rate is restricted by the choke limit where the electrolyte flow in the gap is broken-up and the process is disturbed. This is due to evolved gases which build-up in the machining zone reducing the amount of electrolyte flow. Thus, the electrolyte temperature rises leading to electrolyte boiling and finally to tool damage.

ii. Sparking Constraint.

Sparking is particularly troublesome when high feed rates and low voltages are used specially with passivating electrolytes. Ebeid et al (2) studied the effect of sparking on tool damage under various combinations of voltages, feed rates and back pressures. The results of the regression analysis showed a strong positive correlation between sparking rate and feed rate. Thus, in a computerized machinability data base system, decision should be taken whether to work under sparking conditions or not. For cheap simply designed tools and expensively hourly rates of EC machines it would be more economic to accept low sparking rates and work under high feed rates. On the other hand with complicated designs of tool dies it would be more advantageous to work at low feed rates to avoid tool damage.

Checks are necessary to be performed by the CMDBS to ensure that the recommended working conditions fall within the safe machining regions. Mathematical models are possible to be build up for constraints such as choking and boiling (11) and sparking (2).

2. TOOLING SYSTEM

With ordinary traditional machining processes the selection of cutting tools is more simpler than for the case of non-conventional machining tools. With non-conventional processes special tools have to be designed for specific operations as with the case of dies. However, "Standard" non-conventional tools could be stored in the data files with their shapes, dimensions and tolerances. By "Standard" is meant tools which perform drilling, boring, turning and broaching operations.

Unless the tools are correctly designed and selected from the data base files and due to the complexity of the non-conventional process, problems may arise which hinder the correct performance of the tools. The effect of tool design on the penetration rate for an EDM drilling process has been studied by Ebeid (12). In order to improve flushing conditions and to minimize the hole overcut, the use of button electrodes was recommended. Solid button electrodes improved accuracy but are constrained by the formation of swarf coagulates at the bottom of the drilled hole.

With the case of ECM, broaching tools proved to be beneficial in increasing feed rates (13), improving flushing conditions and attaining higher conformity between tool and workpiece for both triangular and square cross-sectioned tools (14).

Wire-shaped tools proved great success when machining by ECM. This process, which resolves into either slitting or component profiling, is a cost-effective industrial potential in dealing with the difficult-to-cut materials. Previous tests (15)showed the beneficial influence of increased feed rates regarding the desirable reduced width of cut for both rectangular and circular shaped wires.

The following block diagrams demonstrate an example of an integrated machining data selection system. The program enables the selection of the non-conventional process, machining operation, type of tool, working parameters and working medium. The program tests also the possible machining constraints and presents an economical study for the process. For the case of explanation , the program shown below describes a simple ECM drilling operation.

<u>INPUT</u>: REQUIRED JOB: POSITIONING HOLES IN A FORGING DIE
HOLE DIAMETER = 13.5 (+0.0 TO +0.1) MM
HOLE DEPTH = 32 MM
MATERIAL : 50CR V8
CLA VALUE = 2/1000 MM

<u>TERMINAL OUTPUT</u>:

1 <u>TYPE OF PROCESS</u>

ELECTROCHEMICAL MACHINING *
ELECTRIC DISCHARGE MACHINING
ULTRASONIC MACHINING
PLASMA BEAM MACHINING

2 <u>TYPE OF OPERATION</u>

CAVITY SINKING
TURNING
DRILLING *
BROACHING
WIRE CUTTING
GRINDING

* : Denotes selected case.

3 <u>TYPE OF DRILLING</u>

ORDINARY *
FINE
FINE AND DEEP

4 <u>TYPE OF DRILLING TOOL</u>

NO-LAND
BUTTON *
MULTI-LAND

5 <u>SPECIFICATIONS OF BUTTON TOOL</u>

SOLID
WITH THROUGH HOLE *

6 <u>DIMENSIONS OF THROUGH BUTTON TOOL</u>

BUTTON DIAMETER ....
BUTTON HEIGHT ....
SHANK DIAMETER ....
SHANK HEIGHT ....
FLOW DIAMETER ....

7 ELECTROLYTE TYPE

PASSIVATING *
NON-PASSIVATING
ELECTROLYTE/AIR MIXTURE

8 SPECIFICATIONS OF PASSIVATING ELECTROLYTE

CONCENTRATION ....
CONDUCTIVITY ....
BULK TEMPERATURE ....
ADDITIVES ....

9 WORKING PARAMETERS

VOLTAGE ...
FEED RATE ...
INITIAL SETTING GAP ...
EQUILIBRIUM WORKING GAP ...
MAXIMUM CURRENT ...
AVERAGE CURRENT DENSITY ...
FLOW RATE ...
INLET PRESSURE ...
BACK PRESSURE ...
MACHINING TIME ...

10 CONSTRAINTS CHECK

CHOKING LIMIT ....
BOILING LIMIT ....
SPARKING LIMIT ....

11 ECONOMICAL STUDY

MINIMUM MACHINING COST ....
MAXIMUM PRODUCTION RATE ....
MAXIMUM PROFIT RATE ....

The blocks shown in the above program represent what appears on the computer terminal of the user. The blocks appear in such a manner that they are always dependable on each other. For example, if a button tool is recommended by the computer selection, the next block to appear would be concerning specifications about button tools only and any data regarding other types of tools will be automatically excluded. The values of the working parameters are not shown as these may vary slightly according to the type of the mathematical model given in the computer program. The given system is expandable and flexible for any further necessary additions.

CONCLUSIONS

1. A scientific approach for the application of integrated machining data selection systems on non-conventional machining processes has been presented.

2. The study shows the effectiveness of the transfer of machinability data selection from an experienced-based discipline to a computerized information-based discipline.

3. This work aids in standardizing planning schemes for non-conventional processes with the objective of helping process planners, workshop engineers and manufacturers to achieve optimum working conditions.

4. A typical CMDBS example for an ECM drilling process has been presented. The shown system is expandable and flexible to cope with the ever-increasing developments in manufacturing technology.

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